QUARTERLY REPORT

OCTOBER 1994

GRANT NO: N00014-92-J-4099

VIRTUAL REALITY IN PRECISION ENGINEERING RESEARCH

NORTH CAROLINA STATE UNIVERSITY
PRECISION ENGINEERING CENTER

DR. THOMAS A. DOW

Virtual Reality in Precision Engineering Research

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Principal Investigators.

- **PI Names:** Thomas A. Dow, Robert J. Fornaro, Ronald O. Scattergood
- **PI Institution:** Precision Engineering Center, North Carolina State University
- **PI Phone Number:** (919 515-3096
- **PI Fax Number:** (919) 515-3964
- **PI E-mail Address:** thomas_dow@ncsu.edu,
- **PI URL Home Page:** http://www.mae.ncsu.edu/Centers/PEC

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Productivity Measures.

- **Number of refereed papers submitted not yet published:** 0
- **Number of refereed papers published:** 0
- **Number of unrefereed reports and articles:** 12
- **Number of books or parts thereof submitted but not published:** 0
- **Number of books or parts thereof published:** 0
- **Number of project Presentations:** 1
- **Number of patents filed but not yet granted:** 0
- **Number of patents granted and Software Copyrights:** 0

- **Number of graduate students supported >= 25% of full time:** 3
- **Number of post-docs supported >= 25% of full time:** 0

Summary of Objectives and Approach.

1. Develop virtual reality environment for precision fabrication processes and use this environment to study material removal processes and the surface created.

2. Explore computer visualization techniques to enhance the understanding of complicated manufacturing processes.

3. Develop models for brittle fracture and utilize computed images to visualize the resulting surfaces.

Detailed Summary of Technical Progress.

1. Model of Precision Contour Grinding:

Contour grinding creates a surface by moving a grinding wheel across the surface of a workpiece either in a linear motion with a rotating part or by raster scan motion with a stationary part. The interaction of the ellipsoidal wheel with the workpiece creates the geometry of the chip and the surface finish of the workpiece. Unfortunately, the resulting geometry is very complicated due to the large number of interactions (larger than 50) that lead to the finished surface. The geometry was theoretically modeled and a graphics program written to visualize the shape of the chips and the resulting surface. This information along with an understanding of the fracture properties of the brittle materials being ground will lead to improved selection criteria of operating conditions for production of optical and electrooptical components.

2. Geometry of Cup Wheel Grinding:

Cup wheel grinding can be used to produce flat and spherical parts in brittle materials. The part is fed into a tilted cup wheel and a flat, convex or concave shape can be obtained on the part depending on the angle of tilt. Because both the part and the wheel are rotating while the part is being fed into wheel, the geometry of the interactions and the shape of the chips produced are very difficult to visualize. The virtual environment allows the surface and chip features to be viewed and analyzed. This information will lead to a better understanding of the geometric features of grinding and the influence of these parameters on the damage and finish of the surface.

3. Damage Prediction:

The virtual reality model of the grinding process provides the geometry of chip and the conditions leading to the creation of the ground surface. The creation of a surface is a process that involves a number of passes of the wheel. Any specific point on the surface will be machined several times at varying depths of cut and damage can be generated or removed during any of these cuts. A model of the damage is being created and will be compared to experimental measurements.

4. **Diamond Turning Features:**

Certain features observed on diamond turned specimens are difficult to explain. They are potentially due to vibration of the spindle but overlapping cuts mask most of the features necessary to make this conclusion. A surface can be created in the virtual environment and different scenarios can be displayed to understand the source of these surface features.

Transitions and DOD Interactions.

1. Semi-Annual meetings with Affiliates of the Precision Engineering Center including national labs, DOD contractors. Current Affiliates of the PEC are:
    - Aerotech, Inc
    - Kodak
    - Las Alamos National Labs
    - Lawrence Livermore National Labs
    - Rank Taylor Hobson
    - StorageTek, Inc
    - Texas Instruments
    - 3M Corp.
2. Industrial Visits to PEC:
    - David Atwood - Center for X-Ray Optics, UC Berkeley
    - Peter Neumann, Ulrich Vider -
    - David Youden - Rank Pneumo
    - Tim Hoopman - 3M Corp
    - Peter Falter - Westinghouse Corp
    - Stanley Smith - Komag Corp
    - Mark Elkins - IBM
    - Mary Hiles - Siemens
    - John Rimmler, Dave Hammond - Tekelec, Inc
    - Michael Rice, Paul Reiff - Broadband Tech Inc
    - Eric Lee - Gilbreo, Inc
    - Matt Wentz - W&G Inc
    - Jane Alexander - ARPA
    - Paul place - Integrated Device Technology, Inc
    - Kevin Mar - Becton Dickinson Research Center
    - Detlap Hoehl - Duke University
    - Alan Cambell - 3M Corp
    - John Taylor, Mark Piscotty - Lawrence Livermore Natl Lab
    - Ed Stanton - Telecom

- William Snyder, Bog Lawson - EPA
- T. Hatsuzawa - National Research Lab of Metrology, Tsulaba, Japan
- Eric Curtis - OCA Applied Optics
- Mark Martin - Gillette Co
- R. Hassler - Hassler Technical Services
- G. Bae - Samsung Electronics, Korea
- K. Kim - Hyundai Motor Co, Korea
- G. McCavona, A. West, H. Houghton - Rank Taylor Hobson, UK

Software and Hardware Prototypes.

1. **Precision Solid Modeler:** A UNIX-based solid modeling system for formalizing the microscopic interaction of intersecting bodies based on their macroscopic geometries.

2. **PEC Intersection Engine:** Technique for developing complex 3D intersections of solids based on 2D projections from the top down view.

List of Publications.

1. Storz, G. II and Dow, T., "A Practical Guide to Theoretical Modeling of Contour Grinding", PEC Annual Report, 1993, pp. 203 - 222.
2. Storz, G. II and Dow, T., "Theoretical Modeling of Contour Grinding", PEC 1993 Interim Report, pp. 13 - 16.
3. Storz, G. II and Dow, T., "Cup Wheel Grinding Geometry", PEC 1994 Interim Report, pp. 47 - 50.
4. Storz, G. II, "Virtual Modeling of Contour Grinding" Proceedings of ASPE 1993 Annual Meeting, Vol 8, 1993, p193-196
5. Storz, G. II, "Cup Wheel Grinding Geometry", Submitted ASPE 1994.
6. Storz, G. II, "A Practical Guide to Theoretical Modeling of Contour Grinding" submitted ASPE 1994.
7. Storz, G. II, "Theoretical Modeling of Contour Grinding" MS Thesis, Mechanical and Aerospace Engineering, 1994.
8. Bares, W. H. and Fornaro, R. J., "Virtual Reality Visualization of Contour Grinding", PEC 1993 Interim Report, pp. 9 - 12.
9. Bares, W. H. and Fornaro, R. J., "Computer Simulation and Visualization of Contour Grinding", PEC Annual Report, 1993, pp. 183 - 202.
10. Bares, W. H., "Computer Simulation of a Theoretical Model for Contour Grinding", MS Thesis, Computer Science, 1994.
11. Feinberg, J. C. and Fornaro, R. J., "Visualization Issues in the Cup Wheel Grinding Model", PEC 1994 Interim Report, pp. 51 - 54.
12. Sizer, K. B. and Fornaro, R. J., "Enhancement of the Subsurface Damage Model for Contour Grinding Processes", PEC 1994 Interim Report, pp. 55 - 58.

Invited and Contributed Presentations.

1. Fornaro, R. J., ONR Workshop on Virtual Environments, "Geometric Modeling of Contour Grinding", RTP, NC; May 1993.

Honors, Prizes or Awards Received.

1. Scattergood, Ronald O. - Fellow, American Society for Metals, Summer 1994.

Project Personnel Promotions Obtained.

Project Staff.

1. Principal Investigators:
   - Thomas A. Dow, Professor, Mechanical and Aerospace Engineering
   - Robert J. Fornaro, Professor, Computer Science
   - Ronald O. Scattergood, Professor, Material Science and Engineering
2. Research Staff:
   - Ken Garrard
   - Donnie Moorefield
3. Graduate Students:
   - Jim Feinberg, MS Candidate, Computer Science
   - Ken Sizer, MS Candidate, Computer Science
   - Gene Storz, PhD Candidate, Mechanical and Aerospace Engineering

Misc Hypermedia.

Keywords.

1. Precision Engineering
2. Virtual Reality
3. Visualization
4. Brittle Material Fabrication